

FOREST COVER MAPPING FROM 2001 TO 2010 IN LAO PDR, VIETNAM, MYANMAR AND CAMBODIA

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ABSTRACT: 10 years (2001 - 2010) forest covers are generated from MODIS monthly composites (Takeuchi W. and et al. 2010) for ASEAN countries. The auto-generated land covers are needed to validate to match the national and global definition. JAXA provided AVNIR2 images to the SAFE prototypes initiating countries. AVNIR2 image has advantage with better spatial resolution than MODIS. This advantage could be applied to validate the MODIS data. The training forest covers are generated from the AVNIR2 image with the same algorithm to upwards validation. On the other hand, field works are done in Laos, Vietnam, Myanmar and Cambodia. The photographs with positioning information are collected in the field works. National forest covers are validated based on the field data and the training data.

1. INTRODUCTION

The national land covers are generated from MODIS monthly composites for 10 years since 2001 to 2010 (Takeuchi W. and et al. 2010) using the IGBP definition (Belward A. S., 1996). Auto-generated national land covers are published in the SAFE prototype website for Asia countries (www.safe.iis.u-tokyo.ac.jp). Though available land covers are in research level prototype, the validation and verification are require to promote to usable products for the end users. In parallel, GPS photograph database is developing (An, V. N., et al. 2010) for the land cover monitoring. The database has photographs together with geographic latitude, longitude and IGBP code. The IGBP codes are defined together with local forestry experts in the field. In this validation process, the scientific legend which auto-generated from the satellite images with IGBP 17 classes and local legend which interpreted by national standard should be matched based on the GPS photographs information. Though, the study is emphasis on forest cover; the local forestry legends are drawn into the context.

2. LOCAL AND GLOBAL LEGENDS

The study focus on the forest cover mapping in the national level. The auto-generated national forest covers are originated on the global IGBP legends which are generated from the MODIS monthly cloud free composite. Thus, the local forest covers legends from field survey and IGBP land cover from satellite image are compared.

2.1 Local Legend

Cambodia, Lao PDR, Myanmar and Vietnam are located in the tropical and temperate climate region as shown in Koppen Geiger climate map (figure 1). Even though four nations are presented in the proposed study, the paper significantly focus on Myanmar based on her wider range of climate regions and based on the reference data availability on the nation forest legend.

Since 1956, there are 8 standard forest types in Myanmar forestry, namely: 1) tidal forests, 2) beach and dune forests, 3) swamp forests, 4) evergreen forests, 5) mixed deciduous forests, 6) dry forest, 7) deciduous dipterocarp or indaing forest and 8) hill forest (Shien Hoe, T., 1956). Similar forest types are appeared in the status report on the forestry sector of Myanmar (Tint, K. 1995) as tidal forest or mangrove forest, beach and dune forest, swamp forest, tropical evergreen forest, mixed deciduous forest, dry forest, deciduous dipterocarp forest, hill and temperate evergreen forest. The status statistic of the forest type and percentage (NCEA, 2009) is presented in the figure (figure 2).

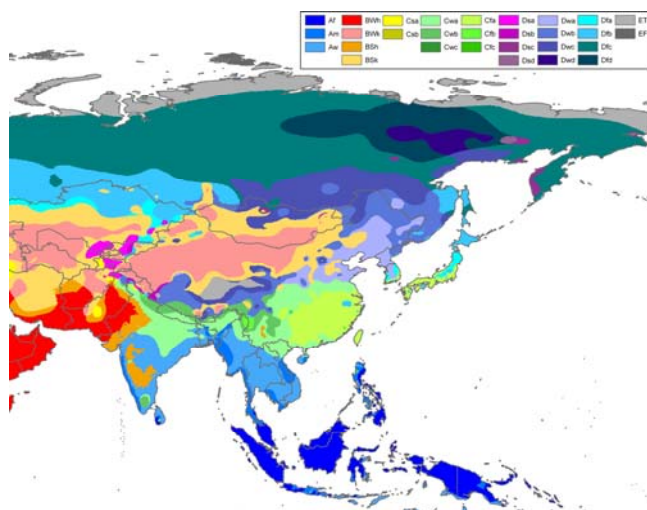


Figure 1. Asia Koppen Map.

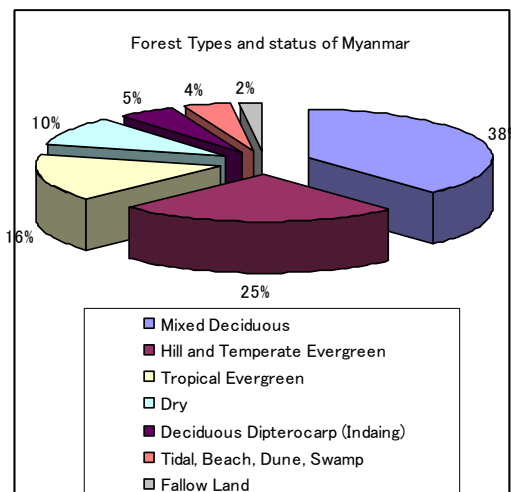


Figure 2. Forest Types of Myanmar

On the other hand, the land cover is defined to 18 classes in Myanmar forestry from the forest management point of view (table 1). The provided GPS photographs are in with the 18 classes specifications. Thus, the photographs are needed to categorize to major forest legend.

Table 1. Forest Type of Myanmar (Source: Forest Department).

No.	Forest Types	Description
1.	Evergreen Forest	Evergreen Forests having a crown density 60% or more. The term “evergreen forest” seemed to refer to forests of high natural characteristics.
2.	Evergreen Forest/Open	Evergreen Forests having largely the same characteristics as item 1 above, but considerable open spaces were seen in the forests.
3.	MUMD forest	Moist Upper Moist Deciduous Forests.
4.	MUMD forest /Open	Mixed deciduous forests with a crown density of 60% or more.
5.	DUMD Forest	Mixed forests with a crown density of less than 60%. A large portion of the forests consisted of with a crown density of approximately 10%. Dry Upper Moist Deciduous Forests. These are mixed deciduous forests, but they display a more define deciduous aspect in the dry season than the MUMD Forests.
6.	Deciduous Dipterocarp forest	Deciduous Dipterocarp forest in which dipterocarpus tuberculatus is the dominant species.
7.	Pine Forest	The distribution of the pine forest started at elevations ranging from 900 m to 1000 m or more.
8.	Hill Forest	Evergreen Forests whose distribution was observed at elevations ranging from 900 m to 1000 m or more.
9.	Dry Forest	Called Indaing Forests in Myanmar, the dry forests are distributed in dry zones. Dry forests had a low crown density.
10.	Bamboo forest	The bamboo forests seemed to be the product of a retrogressive succession of those evergreen forests and MUMD forests which had lost their natural characteristics.
11.	Mangrove forest	Mangrove forests were distributed along of the bay of Bengal.
12.	Mangrove forest/open	Low-density mangrove forest.
13.	Scrubland	Land covered with scrub or young forests.
14.	Grass/agriculture land	Agricultural land was mostly used as rice paddies and field crops are grown in inland areas and highlands.
15.	Orchards/other trees	Fruits trees distributed in the plains & other trees are distributed around rural communities.
16.	Bare land	Includes dry streams beds.
17.	Shifting cultivation	The areas of shifting cultivation are concentrated in the mountain areas.
18.	Water surfaces	Water bodies areas.

According to the forest flora of British Burma (Kurz 1877) the Myanmar forests could be categorized to two main groups: evergreen forests (including littoral forest, swamp forest, tropical forest, and hill forest) and deciduous or leaf shedding forests (open forest, dry forest, mixed forest and dune forest) Thus, the categorization should involve those two major branches in forest mapping process.

Moreover, the four nations' forest types are compared in the table (table 2); although the sources are acquired from the different source; it could be used to understand the regional forest cover.

Table 2. The forest types of four nations.

Cambodia FA type	Lao PDR FIPD type	Myanmar FD type	Vietnam HCS type
1) evergreen forest	1) dry depterocarp	1) tidal or mangrove	1-4) EGB-rich, medium, poor and regrowth
2) semi-evergreen forest	2) lower dry EG	2) beach and dune	5) deciduous forest
3) deciduous forest	3) upper dry EG	3) swamp forest	6) mixed EG and deciduous
4) wood shrubland dry forest	4) lower mixed deciduous	4) tropical evergreen	7) bamboo forest
5) wood shrubland evergreen forest	5) upper mixed deciduous	5) mixed deciduous	8) mixed wood and bamboo
6) bamboo forest	6) gallery forest	6) dry forest	9) coniferous forest
7) others	7) coniferous	7) deciduous	10) mixed broadleaf and coniferous
	8) mixed coniferous/broadleaf	8) dipterocarp or indaing	11) mangrove forest
Source: Forestry administration, Cambodia	Source: World Bank	8) hill forest	12) limestone forest
		Source: Forest Department, Myanmar	13) plantation
			14) limestone area, 15) bare land planned for forestry, 16) water area (lake, big rivers..), 17) Residential area, 18) Other land (Agricultural, transport,)
			Source: FIPI, Vietnam

2.1 Global Legend

As the global legend IGBP definition is used in the study. The legend is acquired by matching Boston University land cover and maximum likelihood classification from the satellite image. The description, classes name and code of IGBP definition are listed in the table (table 3).

Table 3. The IGBP land cover classification (Belward, A., and T. Loveland, 1996).

Code	IGBP class	Description
1.	Evergreen Needleleaf Forests	Lands dominated by trees with a percent canopy cover >60% and height exceeding 2 meters. Almost all trees remain green all year. Canopy is never without green foliage.
2.	Evergreen Broadleaf Forests	Lands dominated by trees with a percent canopy cover >60% and height exceeding 2 meters. Almost all trees remain green all year. Canopy is never without green foliage.
3.	Deciduous Needleleaf Forests	Lands dominated by trees with a percent canopy cover >60% and height exceeding 2 meters. Consists of seasonal needleleaf tree communities with an annual cycle of leaf-on and leaf-off periods.
4.	Deciduous Broadleaf Forests	Lands dominated by trees with a percent canopy cover >60% and height exceeding 2 meters. Consists of seasonal broadleaf tree communities with an annual cycle of leaf-on and leaf-off periods.
5.	Mixed Forests	Lands dominated by trees with a percent canopy cover >60% and height exceeding 2 meters. Consists of tree communities with interspersed mixtures or mosaics of the other four forest cover types. None of the forest types exceeds 60% of landscape.
6.	Closed Shrublands	Lands with woody vegetation less than 2 meters tall and with shrub canopy cover >60%. The shrub foliage can be either evergreen or deciduous.
7.	Open Shrublands	Lands with woody vegetation less than 2 meters tall and with shrub canopy cover between 10%-60%. The shrub foliage can be either evergreen or deciduous.
8.	Woody Savannahs	Lands with herbaceous and other understory systems, and with forest canopy cover between 30%-60%. The forest cover height exceeds 2 meters.
9.	Savannahs	Lands with herbaceous and other understory systems, and with forest canopy

		cover between 10%-30%. The forest cover height exceeds 2 meters.
10.	Grasslands	Lands with herbaceous types of cover. Tree and shrub cover is <10%.
11.	Permanent Wetlands	Lands with a permanent mixture of water and herbaceous or woody vegetation that cover extensive areas. The vegetation can be present in either salt, brackish, or fresh water.
12.	Croplands	Lands covered with temporary crops followed by harvest and a bare soil period (e.g., single and multiple cropping systems.) Note that perennial woody crops will be classified as the appropriate forest or shrub land cover type.
13.	Urban and Built-Up	Land covered by buildings and other man-made structures. Note that this class will not be mapped from the AVHRR imagery but will be developed from the populated places layer that is part of the Digital Chart of the World (Danko, 1992).
14.	Cropland/Natural Vegetation Mosaics	Lands with a mosaic of croplands, forest, shrublands, and grasslands in which no one component comprises more than 60% of the landscape.
15.	Snow and Ice	Lands under snow and/or ice cover throughout the year.
16.	Barren	Lands made up of exposed soil, sand, rocks, or snow which never have more than 10% vegetated cover during any time of the year.
17.	Water Bodies	Oceans, seas, lakes, reservoirs, and rivers. They can be either fresh or salt water bodies.
18.	Tundra	Lands defined by IGBP to be Barren where the Olson vegetation map, when overlaid on top of the IGBP defines these locations to be type "Tundra".

3. AUTO-GENERATED LAND COVER MAP

The land cover auto-generation algorithm from MODIS monthly composite (Takeuchi, W., et al., 2010) uses IGBP 17 classes defined by the International Geosphere Biosphere Programme to map the national land cover. Although, IGBP legend has 17 classes; the auto-generated classes are fewer in national level (table 4). Thus, the classes could be increase by validating with GPS photographs.

Table 4. Auto-generated IGBP classes for the four countries.

IGBP NAME	Cambodia	Lao PDR	Myanmar	Vietnam
water	0	0	0	0
evergreen broadleaf	2	2	2	2
mixed forest	5	not present	5	5
woody savannas	8	8	8	8
savannas	not present	9	not present	not present
croplands	12	12	12	12

The auto-generated land cover matched only 6 classes from IGBP 17 classes for the region (table 4). Water body and evergreen broadleaf, woody savannas and croplands are common for the four nations. Once savannas appeared in Lao PDR; mixed forest is disappeared in the country. Although 6 IGBP classes are automatically mapped by the algorithm of MODIS monthly composite; the class appearances are unstable in year by year.

4. VALIDATION USING GPS PHOTOGRAPHS DATABASE

4.1 Data Simplification

The GPS photographs database development is performing in parallel (An, V. N., et al., 2010). More that 5,000 GPS photographs are collected in the database together with IGBP definition in each photograph. Most of the GPS photographs are collected using GPS tracking technique. Thus, many GPS photographs could be accumulated in a pixel location of satellite image while the satellite image's spatial spacing is larger. In the case of MODIS image for the national level land cover generation the study used 250 meters by 250 meters pixel size. Thus, it is required to remove redundance points for each pixel or from the specific extent of the area. Moreover, some track route has several GPS photos points thus the grid filtering methodology is introduce to reduce the redundancy (figure 3). After the processes are performed a lot of unusable GPS points are removed (table 5).

GPS Photos	Original Amount	Simplified Amount
Cambodia	not concern	not concern
Lao PDR	4508	460
Myanmar	355	173
Vietnam	154	91
Total	5,017	724

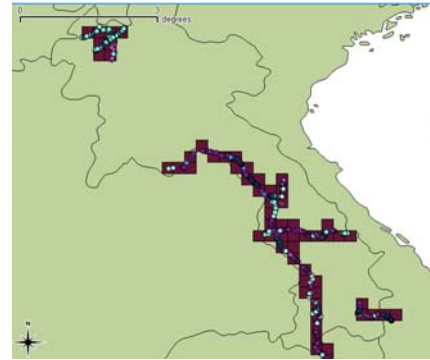


Table 5. Simplified GPS photographs.

Figure 3. 0.25° grid to remove accumulated points.

4.2 Land Cover Validation

Based on the GPS photographs, AVNIR2 image and Google Earth the following IGBP classes (table 6) are covered the selected nations. There are only 5 IGBP classes are assigned by auto-generation algorithm in the case of Myanmar. They are water in code 0, evergreen broadleaf forest in code 2, mixed forest in code 5, woody savannah in code 8 and croplands in code 12. The confusion matrix of the code assignment is presented in table (table 6). While the IGBP codes filtered from GPS photo using 173 GCP with 50 maximum likelihood unsupervised classes, IGBP classes assignment is increased to 8 such 0, 2, 4, 5, 6, 8, 10 and 12. Thus, the validation process could increase the land cover classes mainly for forest cover perspective.

Table 6. Assignment of GPS photos to IGBP for Myanmar.

IGBP Name	water	EGB	Deciduous	Mixed	Close shrubland	Woody savannas	Grassland	croplands
Water	0	-	-	-	-	-	-	-
evergreen broadleaf	0	2	4	5	6	-	-	12
mixed forest	0	2	4	5	-	-	-	-
closed shrubland	-	-	-	-	-	-	-	-
woody savannas	-	2	4	5	6	8	-	-
croplands	0	2	4	5	6	8	10	12

6. RESULT AND DISCUSSION

Table 7. Confusion matrix of year 2001.

Overall Accuracy = 52%

IGBP	0	2	4	5	6	8	10	12	13	14	16
0	5	1	0	0	0	0	0	0	0	0	0
2	1	13	4	0	0	0	0	1	0	0	0
4	0	1	58	0	0	2	0	5	0	0	0
5	0	0	2	0	0	0	0	0	0	0	2
6	0	1	4	0	0	0	0	1	0	0	0
8	0	0	7	1	0	1	0	4	0	0	0
10	0	1	3	1	0	0	0	3	0	0	0
12	0	1	9	1	0	2	0	13	0	0	0
13	0	0	8	1	0	0	0	3	0	0	0
14	0	0	3	1	0	0	0	1	0	0	0
16	0	0	4	0	0	0	0	6	0	0	0
	6	18	102	5	0	5	0	37	0	0	173

Table 8. Confusion matrix of year 2010.

Overall Accuracy = 54%

IGBP	0	2	4	5	6	8	10	12	13	14	16
0	4	2	0	0	0	0	0	0	0	0	0
2	0	9	5	3	0	0	0	2	0	0	0
4	0	1	51	1	0	1	5	7	0	0	0
5	0	0	2	0	0	0	0	0	0	0	2
6	0	0	2	1	2	0	0	1	0	0	0
8	0	0	3	0	0	6	1	3	0	0	0
10	0	1	2	0	0	1	1	3	0	0	0
12	0	0	5	1	0	0	0	20	0	0	0
13	0	0	4	0	2	2	0	4	0	0	0
14	0	0	0	0	0	0	1	4	0	0	0
16	0	0	2	0	0	2	2	4	0	0	0
	4	19	76	6	4	12	10	48	0	0	173

The result presented with confusion matrices for year 2001 (table 7) and 2010 (table 8) for Myanmar. The result shows that virtual interpretation on the GPS photos accuracy is just above the 50 percent. Thus, it is required to improve the virtual interpretation accuracy of GPS photos to IGBP definition. Moreover, the error may come from

the virtual interpretation of the photos to IGBP code and time difference of field survey. The size of land cover appeared in the photographs and the size of image pixel should draw to account to improve accuracy.

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